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SEISMIC DATA LABORATORY
QUARTERLY TECHNICAL SUMMARY REPORT

JANUARY - MARCH 1970

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By

SEISMIC DATA LABORATORY

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SEISMIC DATA LABORATORY
QUARTERLY TECHNICAL SUMMARY REPORT
January - March 1970

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ABSTRACT

This report summarizes the work done by the SDL during the period January through March 1970, and is primarily concerned with seismic research activities related to the detection and identification of nuclear explosions and earthquake phenomena. Also discussed are the support tasks and data services performed for other government contractors and participants in the VELA-Uniform and PRIME ARGUS projects.

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I. INTRODUCTION

This quarterly report summarizes the technical work, support effort, and service tasks completed during the period January through March 1970. Current and past work are mentioned only if related to the present discussions.

Reviews of technical reports completed during the reporting period are contained in Section II under descriptive headings. Section III is a summary of the support and service tasks performed for other government contractors, and for VELA-Uniform and PRIME ARGUS participants.

II. WORK COMPLETED

A. Seismoprints

This study describes contour spectrograms (seismoprints) of short-period P and P-coda signals which are used to display power as a function of frequency and time. Analyses of LONG SHOT and an Andreanof Island earthquake (22 November 1965) by means of seismoprints effectively show the complex time-frequency-power relationships within the earthquake's P-coda; the explosion prints exhibit much simpler signatures. This suggests that volume integrals derived from earthquake and explosion seismoprints can be used to compute complexity factors. For the explosions, repetitive, characteristic signatures are found for the P and P_cP arrivals (and for the P- and P_cP-codas).

B. A Location and Travel-Time Study of Aleutian Islands Explosions and Earthquakes

Travel-time anomalies from the LONG SHOT explosion on Amchitka Island are used in this analysis to locate the Flexbag explosion approximately 70 km southwest of LONG SHOT. The results obtained using anomalies and various teleseismic networks indicate location errors less than about 10 km. Without anomalies, the location errors are 5-25 km. Comparable results are obtained when Flexbag anomalies are used to locate LONG SHOT.

In addition to the location of the explosions, 52 Aleutian Islands earthquakes, previously located by the USC&GS, were relocated using LONG SHOT anomalies. That the anomalies are valid in the immediate area of LONG SHOT and useful over a larger area is illustrated by locating 25 of these earthquakes with an eight station common network both with and without LONG SHOT anomalies. The pattern of the resultant location shifts provides insight into the problems of location stability, network resolution, and location bias.

C. Dependence of Theoretical and Observed Rayleigh-Wave Spectra on Distance, Magnitude, and Source Type

Theoretical source spectra which are closely tied to empirical evidence from explosions and earthquakes are presented in this report. The effects of the transfer functions of a layered media upon the source spectra are shown, and a theoretical earthquake-explosion spectral ratio is defined for Rayleigh waves. Using spectral estimates on many widely distributed events, it was found that explosions and earthquakes can be separated by splitting Rayleigh-wave energy between 10 and 50 seconds into two period bands and calculating their ratio. Explosion ratios are confined to a narrow range. Earthquake ratios have a large scatter because they depend on depth and source mechanism parameters.

D. Frequency Dependent Estimation and Detection for Seismic Arrays

This report describes a frequency dependent detection and estimation procedure based on the generalized likelihood principle which is applied to several models appropriate for vertical and horizontal seismic arrays. When data were constructed so as to conform to the idealized model, excellent agreement with theoretical detection limits is shown. Multiple signal models were analyzed in the frequency domain with the presence of various signal components indicated in terms of power spectral ratios. Tables of the central and non-central F distribution were used to determine false alarm and signal detection probabilities.

Two models were assumed in analyzing data from vertical arrays. A full model, assuming each time series to be composed of a ghosted signal and an infinite velocity noise component, indicated that, in general, the infinite velocity component is not present in the "signal plus noise" or the "noise only" cases. A reduced model containing only a ghosted signal plus noise accounted for as much power and produced as good a signal estimate. The signal estimates in general tended to be point by point reproductions of the surface trace indicating that a significant signal to noise enhancement will be difficult using a simple processor. Detection results indicate that in "signal plus noise" cases with a high signal to noise ratio the F statistic exceeds a threshold which would occur by chance much less than one time in 2000. However, "noise alone" analysis also gives a significant (although much less so) value over all frequencies indicating the presence of P waves in the noise. Further analysis on other arrays where the fundamental Rayleigh mode is

known to be prominent and where there are lower signal to noise ratios should establish the usefulness of the detector. Analysis of the statistics of the ambient P-noise can also be performed.

For the horizontal array, results using real data indicate that the F statistic, can be a more sensitive detector than the phased sum alone. Examples for the "signal plus noise" case indicate that the signal is detected with a high probability. The "noise alone" analysis yields a low false alarm rate in the particular cases analyzed. Further research can establish the effectiveness of the statistic in determining which frequencies propagate with the signal velocity as well as the level of detection possible with errors in the time delays and sensor calibrations. Models which combine vertical and horizontal arrays are yet to be investigated.

E. A Comparison of the Lake Superior and Nevada Test Site Source Regions

This study documents in detail two particular source regions, Lake Superior and the Nevada Test Site, using available geological and geophysical observations. Each is discussed individually in relation to its setting in the prevailing regional crust and upper mantle structure of the mid-continent and the Basin and Range respectively. Comparison of the two source areas indicates that they are markedly different from one another not only at shallow depths but throughout the upper mantle as well. Location accuracies for events at both sites are quite comparable. A large bibliography documents the extensive literature relevant to Lake Superior and the Nevada Test Sites.

F. A Long-Period Noise Study at Murphy Dome, Alaska

In this investigation long-period signals and noise samples recorded at Murphy Dome, Alaska, on standard LRSM instruments and the Geotech triaxial seismometer were subjected to spectral analysis. System noise tests showed that recorded seismic noise was limited to a band from .02 to 0.3 cps. Spectra representing many recording periods between January and August 1969 revealed the background noise to be of variable character and the RMS to range from 2.5 millimeters to 5.2 millimeters on a trace magnified 10^5 times with the standard LRSM system response. Due to its location at depth the triaxial instrument significantly reduced background noise on horizontal components caused by atmospheric pressure changes. Coherence between triaxial components of motion and corresponding LRSM components was excellent for most signals analyzed.

G. Analysis of Strain Seismograph Data

The purpose of this study was to describe the noise fields at several sites and to develop methods of signal enhancement using strain seismometers. Results indicate that in the response band of the short period pendulum and strain instruments, there are approximately four decades of relative noise power at HNME, and two decades at WMO. In one case analyzed the noise power at HNME is about $2\frac{1}{2}$ times the noise power at WMO at 1 Hz.

Coherence was estimated as a measure of the existence of a linear transfer function between the vertical strain and the vertical pendulum. The HNME data were used to define a linear transfer function in the band 0.1 to 0.6 Hz. The low coherence at higher frequencies at HNME and throughout the 0.1 to 3.0 Hz band at WMO rule out the possibility of a linear transfer function between the vertical strain and vertical pendulum.

Multiple coherence, and rotation of the horizontal short period seismograms were used to infer the existence of unidirectional noise components. At HNME about 80 percent of the noise power is unidirectional in the 0.3 to 0.4 Hz band. At WMO the noise field has no apparent single preferred direction. Preliminary work on rotation of the horizontal strain instruments at WMO is presented. The technique uses a third horizontal instrument to establish the shear component of strain.

Examples of detailed analysis are included in the report to establish wavetype using the vertical strain recording together with the horizontal and vertical pendulum outputs.

III. SUPPORT AND SERVICE TASKS

In addition to the research described above, the SDL performed certain service tasks as follows:

A. Data Cataloging, Classifying, and Retrieval

The library contains digitized seismograms, digital and analog magnetic tapes, 16 and 35 mm film data. Station logs corresponding to each data set are arranged chronologically by stations either in loose-leaf binders or in file cabinets.

At the end of the first quarter of 1970 the library contains approximately:

14,884 digitized seismograms;
4,850 digital magnetic tapes;
29,312 analog magnetic tapes;

as well as 16 mm film data recorded at seismic observatories during the period September 1960 to the present, and 35 mm film data recorded at LRSM stations during the interval September 1961 to the present. The increase in digital tapes reflects a transfer of the LASA data file during February.

Although the proportion of digital tapes assigned to a specific function changes constantly, the library consisted of the following groups at the end of the reporting period:

279 UBO multiplexed;
44 UBO demultiplexed;
1,575 LASA demultiplexed;
522 LASA demultiplexed;
402 TFO-37 multiplexed;
84 TFO-37 demultiplexed;
98 TFO-37 permanent data;
1,946 Scratch, save and A/D.

The analog magnetic tape library consisted of the following groups at the end of March:

8,611 compressed;
3,150 uncompressed (6 months intentional backlog);
484 composites;
17,494 save;
700 shipped;
273 received.

B. Equipment Modifications

No equipment modifications were made during the quarter. However, the systems group was successful in its attempts to operate the 763 Calcomp Plotter in the incremental and zip mode. The 763 plotter is now a part of the system.

C. Maintain and Operate Equipment

Equipment maintenance engineers were on duty two full shifts each day and were on standby for the remaining shift. During the reporting period their tasks included preventive and corrective maintenance.

Preventive maintenance was performed daily on all equipment in accordance with equipment maintenance manuals. The digital system received three additional performance checks on a monthly basis.

Corrective maintenance was performed on the main frame of the 1604-B computer and the disk file. We have replaced several major parts on the disk, and additional parts are on order for spares.

The air-conditioning requirements for the computing room have increased to the point where action is being taken to prevent equipment over-heating. We have submitted the necessary documents for approval to purchase additional air conditioners.

D. Digital Programming

The CALCOMP Standard Plotting Package for the 763 Plotter is now in use. The standard Plotting Package is comprised of a large number of routines written to ease the programming requirement necessary for the presentation of graphical data. These routines, some of which may have been previously listed, are:

AXIS - Plots an annotated axis with "tic" marks and labels.

CIRCLE - Plots a circle, arc, or spiral starting at a given point.

CNTRLN - Plots broken center lines between successive data points.

CURVEX - Plots a function of X over a given range.

CURVEY - Plots a function of Y over a given range.

DASHLN - Plots dashed lines connecting a series of data points.

ELIPS - Plots an ellipse or elliptical arc.

FACTOR - Used to magnify or demagnify an entire plot.

FIT - Plots a semi-hyperbolic curve through three data points.

GRID - Plots a linear grid.

LGAXIS - Plots a logarithmic axis with annotation.

LGLINE - Plots data in either a log-log or semi-log mode.

LINE - Scales and plots data with either connected or disconnected points.

NOZIP - Disables the zip mode of operation.

NUMBER - Plots formatted numbers as computed by the user program.

PLOT - Converts all plotting data from inches to plotter related movements and controls all tape buffering with no program intervention.

PLOTFIN - Closes a plotting file.

PLOTOP - 160-A routine used to convert data written on tape to actual plotter commands.

PLOTS - Opens a plotting file

POLAR - Scales and plots a radial variable against an angular variable.

POLY - Plots equilateral polygons.

RECT - Plots rectangles.

SCALE - Computes scale factors to convert user units to plotter units.

SCALOG - Scales logarithmic plotting data.

SMOOTH - Plots a smooth line through a set of data points.

STSMBOL - Allows user to redefine symbol set.

SYMBOL - Plots alphanumeric text and special symbols.

TELBIRD - Plots the Teledyne symbol.

WHERE - Provide the user with the current pen position and FACTOR values.

ZIP - Re-enables the zip mode of operation.

COOPNAME - Allows the user access to the name field of the COOP Card.

The following programs were written during the first quarter:

PROGRAM BEAMSAN: Was revised to read calibrations either from cards in the case of long-period data or from tape for short-period data. Labeling was also changed to update the label.

PROGRAM PLOTOZ: Plots all channels of a seismogram using the same scale factor.

PROGRAM POWRAMP: Computes power ratio, amplitude ratio, and the Q of the inner core.

PROGRAM PRNTENNT: Prints out card images of event groupings.

PROGRAM TESTUNK: Was modified to insert a quadratic data reconstruction subroutine.

PROGRAM LEHMR2: The polynomial root finder program is working. A series of checkout runs is in progress. The purpose of these is to find the limits of the program.

The following subroutines were written during the first quarter:

SUBROUTINE CNTREN: A Fortran Calcomp Plotter subroutine which draws "center lines" between successive data points.

SUBROUTINE POLAR: Uses Calcomp Plotter to plot an array of data points in polar coordinates.

SUBROUTINE DASHLN: Uses Calcomp Plotter to draw dashed lines connecting an array of data points.

SUBROUTINE ARROW: This is a Calcomp plotting subroutine which draws a line through a series of data points and places an arrow at the end.

SUBROUTINE FLINE: This is a Calcomp plotting subroutine which plots data from an array. It applies predetermined scaling parameters to the data coordinates to guarantee that the plotted data fits within prescribed dimensions. Control is provided for annotating the data points with centered symbols and/or for drawing straight lines or smooth curves through each successive data point.

Conversions to the new plotting system are as follows:

PZS2PLOT

BEAMSAN

ARZERZ2

MPLCT

ARRAYSAN and LOPAZ 630 were converted to the 763 plotter. These two programs appear to work alright but need writeups, binary decks, etc.

The conversion of the CDC 6400 contour plot subroutine is in progress.

PROGRAM AUTOLFT has been converted to produce plots on the 763 plotting system.

PROGRAM SUBSETSL has been converted to produce plots on the 763 plotting system.

PROGRAM COLLAPSE has been converted to produce plots on the 763 plotting system.

The following revision was made during this quarter:

TIMEFIND - This program was changed to obtain the correct year and to print out extra parameters.

E. VELA and PRIME ARGUS Data Copies

During the period 01 March 1969 through March 1970, the SDL supplied data services to the following:

Lawrence Radiation Laboratory
Pennsylvania State University
University of California
MIT, Lincoln Laboratory
Geotech, Garland
U.S. Coast & Geodetic Survey
U.S. Geological Survey
National Aeronautics and Space Administration (NASA)
University of Michigan

Stanford Research Institute
Brown University
Princeton University
Environmental Science Services Administration (ESSA)
St. Louis University
University of Texas at Dallas
Lamont-Doherty Observatory
Southern Methodist University
General Atronics

F. Analog Tape Compression

During the first quarter of 1970 we compressed 1617 field tapes. A total of 1400 degaussed tapes were returned to the Dallas facility.

G. LASA Data Service

LASA weekly event summaries as well as film and tape copies were made and distributed. During the interval 01 March 1969 through March 1970, the SDL has supplied LASA and LAMA data copies to the following:

U.S. Geological Survey
Isotopes
MIT, Lincoln Laboratory
Stanford University
University of Wisconsin
University of Michigan
Air Force Office of Scientific Research
St. Louis University
Southern Methodist University
New Mexico Tech
University of Bergen, Norway
University of Western Ontario
Seismic Array Analysis Center (SAAC)
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12. ABSTRACT

This report summarizes the work done by the SDL during the period January through March 1970, and is primarily concerned with seismic research activities related to the detection and identification of nuclear explosions and earthquake phenomena. Also discussed are the support tasks and data services performed for other government contractors and participants in the VELA-Uniform and PRIME ARGUS projects.

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